Appendix G

Tunnel Concept Report

TUNNEL CONCEPT REPORT

FLORIDA DEPARTMENT OF TRANSPORTATION

Financial Project Number: 410844-1-A8-01
Federal Project Number: 7777-087-A

Crosstown Parkway Extension
From Manth Lane to U.S. 1
St. Lucie County, Florida

The project will extend the Crosstown Parkway from Manth Lane on the west, across the North Fork St. Lucie River (NFSLR) to U.S. 1 on the east.

AUGUST 2012

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1.0 Introduction

The Federal Highway Administration (FHWA), in cooperation with the Florida Department of Transportation (FDOT), has prepared an Environmental Impact Statement (EIS), including a Section 4(f) Evaluation, in association with the Crosstown Parkway Extension Project Development and Environment (PD&E) Study. The PD&E study and the EIS were conducted by the City of Port St. Lucie (City) through a Local Agency Program (LAP) Agreement with FDOT, District 4.

1.1 Purpose and Background

The project is needed because currently, the existing bridges within the City across the North Fork St. Lucie River (NFSLR) are experiencing significant traffic congestion and will not be able to meet the projected travel demand across the NFSLR in the future. Based on the FDOT generalized values for roadways, if the daily traffic on a roadway is higher than the generalized volumes, this indicates that a roadway has congestion during the peak hours (morning and afternoon rush hours). Based on a comparison of daily volumes along the bridges to the generalized service volume thresholds contained in the FDOT Quality/Level of Service Handbook, the existing bridges are operating at Level of Service F (generally characterized by intersection congestion, extremely low speeds, high delays, high volumes, and extensive queuing). This condition creates significant traffic congestion along area roadways, threatening the safety and long-term viability of these corridors. This demand is projected to increase, and the current congested conditions will worsen. Traffic analyses conclude that this high degree of traffic congestion cannot be alleviated by localized intersection improvements or improvements to the existing bridges. Even if both bridges were widened, the demand to cross the NFSLR would still exceed the capacity, and the improved bridges would still constrain the ability of the roadway network to process transportation demand across the NFSLR.

The primary purpose of this project, therefore, is to relieve the existing corridors of their highly congested conditions and provide additional east-west capacity to address the traffic impacts from recent and projected growth in the area. To address this need, a new 6-lane divided highway is proposed from the existing Crosstown Parkway to U.S. 1.

The need for the project has long been recognized by the City, St. Lucie County (County), and State authorities as evidenced by the project's inclusion in the following documents:

- The City of Port St. Lucie Comprehensive Plan (adopted 1998 and amended in 2003);
- The St. Lucie County Metropolitan Planning Organization's (MPO) 2025 Long Range Transportation Plan (adopted in 2001);
- The 2030 Regional Long Range Transportation Plan (RLRTP), Martin and St. Lucie Counties Metropolitan Planning Organizations, updated September 2008;
- The 2035 RLRTP, Martin and St. Lucie Counties, updated February 2011;
- The 2002 Martin and St. Lucie Counties Regional Land Use Study;
- The 2004 Urban Land Institute - Port St. Lucie, Florida Panel Report; and
- The Florida Department of Transportation Work Program - Fiscal Years 2011-2015.

Further discussion on the purpose and need for the project is provided in the EIS prepared for this project.

All of the bridge alternatives under consideration would necessarily have to cross the environmentally-sensitive NFSLR Aquatic Preserve, and five of the six alternatives would impact the Savannas Preserve State Park. Therefore, paramount to the project is meeting the Parkway safety and capacity needs while minimizing adverse impacts to the environment. This *Tunnel Concept Report* is provided to evaluate the viability of the Crosstown Parkway Extension project as a tunnel extending beneath the NFSLR as an alternative to constructing a bridge. The primary focus of the evaluation is to avoid impacts to the environmentally-sensitive preserve and State-owned lands.

Photo 1: View of the NFSLR in Project Study Area

There are several unique considerations to be weighed when constructing a tunnel. The focus of this *Tunnel Concept Report* is to evaluate the overall feasibility of a tunnel concept at the NFSLR project location relative to alternative bridge concepts under consideration by outlining general considerations such as cost, geometric constraints, safety, security, property impacts, air quality, noise level, and pedestrian-related concerns. The possible beneficial impacts that are evaluated in this *Tunnel Concept Report* include: minimizing environmental impacts, improving aesthetics, and avoiding interference to waterborne traffic operations. A detailed investigation of the many important technical and non-technical issues related to underground construction is considered to be outside the scope of this *Tunnel Concept Report*. More detailed technical criteria and guidance for the planning and design of road tunnels can be found in resources, such as the U.S. Department of Transportation Federal Highway Administration Road Tunnel Design Guidelines (2004).

1.2 Primary Assumptions

This *Tunnel Concept Report* is based upon several primary assumptions to provide a uniform approach to the design of a tunnel road project that will yield a comparative analysis with the bridge alternatives being considered:

- Number of Traffic Lanes: For the purpose of this Report, it is assumed that each tunnel would carry three lanes of traffic although certain tunnel construction methods limit the number of traffic lanes; e.g., circular tunnels are often limited to two lanes of traffic or less.,
- Pedestrians: Tunnel facilities for pedestrians and cyclists may be considered disproportionately costly when incorporated into a vehicular tunnel system because the size of the tunnel must be increased. For the purpose of this Report, it is assumed that any tunnel concept will carry the sidewalks and bicycle lanes required for the Crosstown Parkway.
- Environmental Impacts: Tunnel projects may introduce environmental impacts resulting from ground movements (heave, settlement, etc), influence on groundwater, chemical grouting, construction by-products, leakage of underground oxygen-deficient air/hazardous gases, and pushing organic material or iron-content soil into nearby wells. For the purposes of this Report, considerations regarding environmental impacts are limited to impacts resulting from the overall tunnel footprint only.

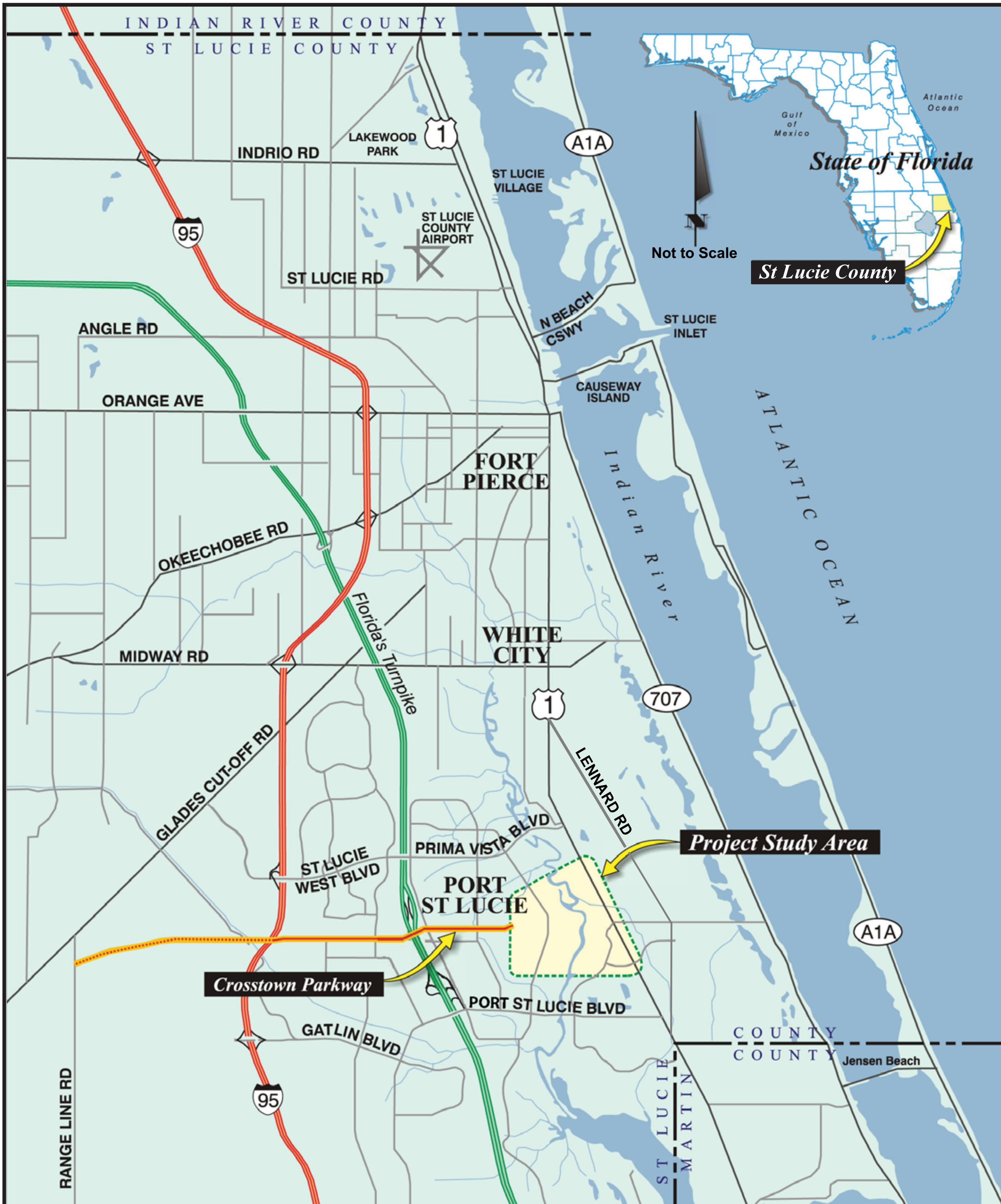
1.3 Project Description

The project is located in the City of Port St. Lucie, St. Lucie County, Florida. The study area is bordered on the north by Fallon Drive, the south by Thornhill Drive, the west by Manth Lane, and on the east by U.S. 1 (also known as S.R. 5). The location of the project is shown on Figures 1.3.1 and 1.3.2.

The project will construct a 6-lane divided highway to serve multimodal transportation alternatives, including automobile, bicycle, pedestrian, and public transit. Alternatives evaluated in the EIS included the No Build Alternative, transportation systems management alternatives, and multiple build alternatives that provide a river crossing on a new bridge alignment. The build alternatives are depicted on Figure 1.3.3 and are described below:

- <u>Alternative 2A</u> – Connects Crosstown Parkway via Walters Terrace west of the NFSLR to Veterans Memorial Parkway east of the NFSLR and ultimately connects with U.S. 1 at the intersection of Walton Road;

- <u>Alternative 2D</u> – Extends Crosstown Parkway along West Virginia Drive to Floresta Drive, then connects to Walters Terrace via Floresta Drive. Traffic would be required to make right and left turn movements at the two intersections along Floresta Drive to make the connection to U.S. 1;



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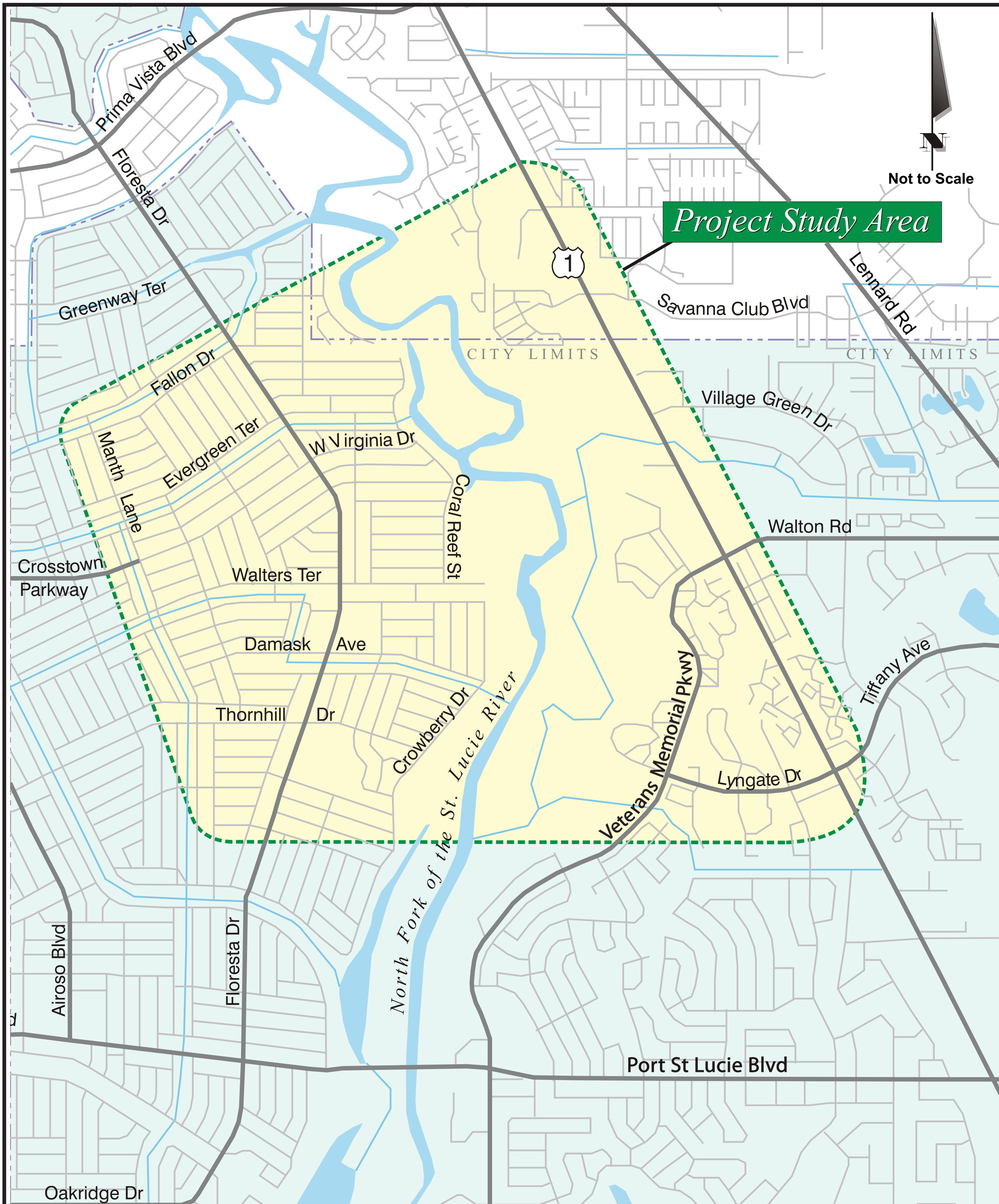
Crosstown Parkway Extension PD&E Study and
Environmental Impact Statement

Regional Location Map

Figure 1.3.1



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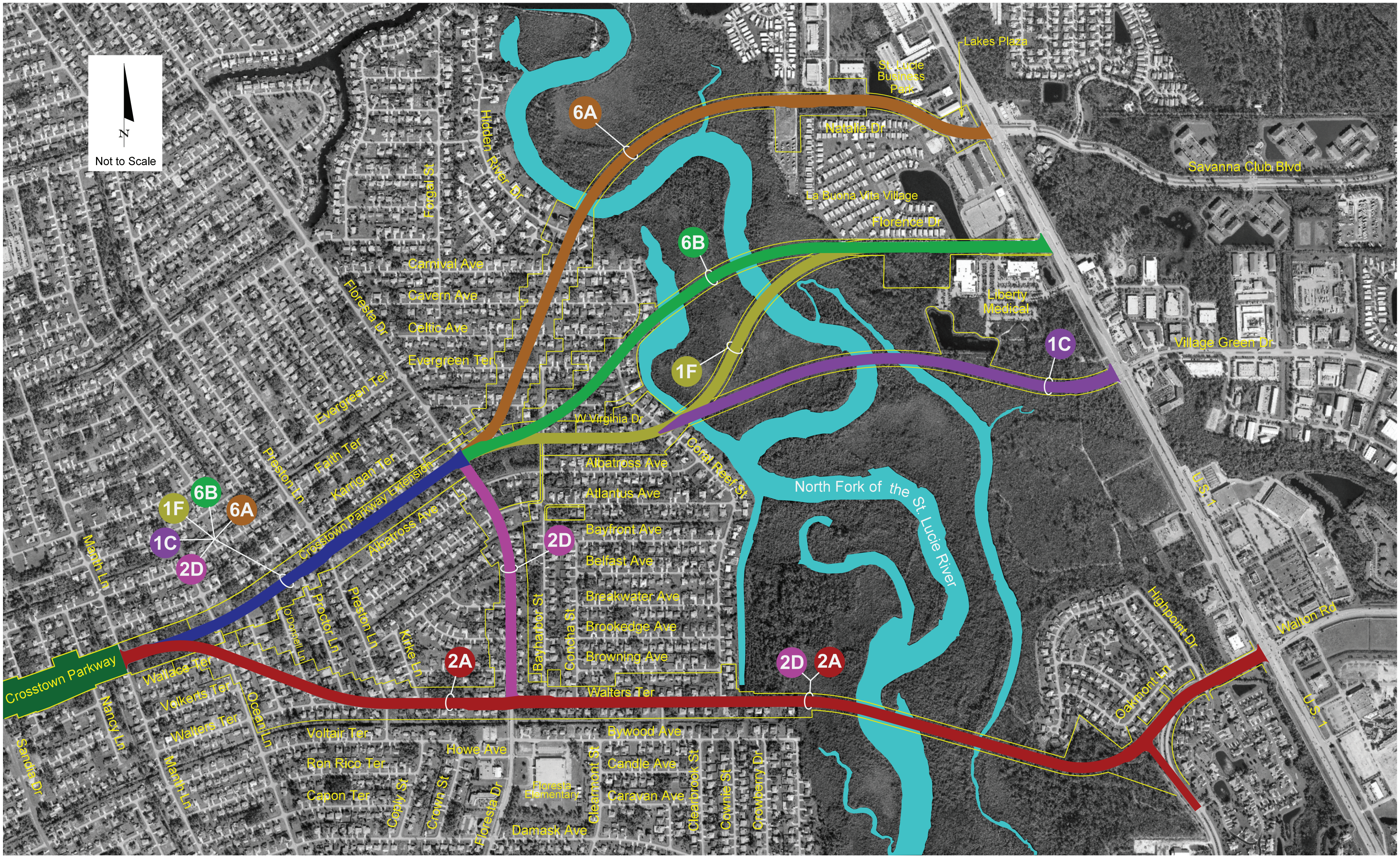
Crosstown Parkway Extension PD&E Study and Environmental Impact Statement

Project Study Area

Figure 1.3.2



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Build Alternative

Figure 1.3.3

- Alternative 1C – Connects Crosstown Parkway along West Virginia Drive west of the NFSLR to the existing intersection of U.S. 1 and Village Green Drive;

- Alternative 1F – Extends Crosstown Parkway along West Virginia Drive, then curves northeast between the river banks, and connects with U.S. 1 at a new intersection between Village Green Drive and Savanna Club Boulevard;

- Alternative 6B – Similar to 1F, this alternative extends Crosstown Parkway along West Virginia Drive to Floresta Drive. However, it curves northeast beginning at Floresta Drive and crosses the NFSLR north of Alternative 1F. It connects with U.S. 1 at a new intersection between Village Green Drive and Savanna Club Boulevard; and

- Alternative 6A – Extends Crosstown Parkway along West Virginia Drive to Floresta Drive. From there it curves north and then east across the NFSLR to the existing intersection of U.S. 1 and Savanna Club Boulevard.

1.4 Tunnel Types

The NFSLR has relatively soft geological conditions which include sands and silts. These conditions are generally suitable for the use of the following types of tunnel construction:

- Immersed Tube Method: Prefabricated tunnel segments are constructed off-site and transported to the location. The segments are lowered/sunk into place and then assembled underwater (Figure 1.4.1)..
- Cut and Cover Method: After the tunnel alignment is excavated or "cut", the tunnel is then formed within the excavation by constructing a foundation, walls, and roof etc. within the excavation, and then backfilling or "covering" the completed tunnel (Figure 1.4.2).
- Tunnel Boring Machine (TBM) Method: A machine bores through the ground under the river bottom (Figure 1.4.3) without disturbing the ground surface except at the tunnel begin and end points. While excavating the soil, a tunnel liner of reinforced concrete panels is placed behind the machine as it progresses further into the earth. The soil is extracted through the completed portion of the tunnel. Although relatively costly, the TBM Method is generally recognized as the preferred tunneling method when the project requires that the ground surface remain undisturbed.

The advantage of the Immersed Tube Method is that the prefabricated tunnel components are less expensive when compared to a bored tunnel. The Immersed Tube Method is also considered more viable for tunnels with considerable length under water, as the prefabricated tunnel segments are fabricated off site in a controlled environment, transported to the project by barge, and installed from above. The majority of the Crosstown Parkway tunnel area, however, is underground, with limited portions under water. Additionally, there are significant environmental impacts that occur during the open trenching necessary for the installation of prefabricated tunnel segments. Because preservation of resources is a primary focus of the Crosstown Parkway Extension project, the advantages of constructing an Immersed Tube Method tunnel at this location are considered minimal. Therefore, the Immersed Tube Method is not considered a viable alternative.

Note: Prefabricated Tunnel Tube Being Prepared to Sink into Place

Central Artery Project in Boston Harbor - Public Broadcasting System

Marmaray Project, Turkey - Wikipedia

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Prefabricated Tunnel Tube

Figure 1.4.1

Note: Cut and Cover Tunnel - Excavation, Walls and Roof Construction

Fort Henry Tunnel in Baltimore, Maryland from 1984. (Scott Kozel photographer.)

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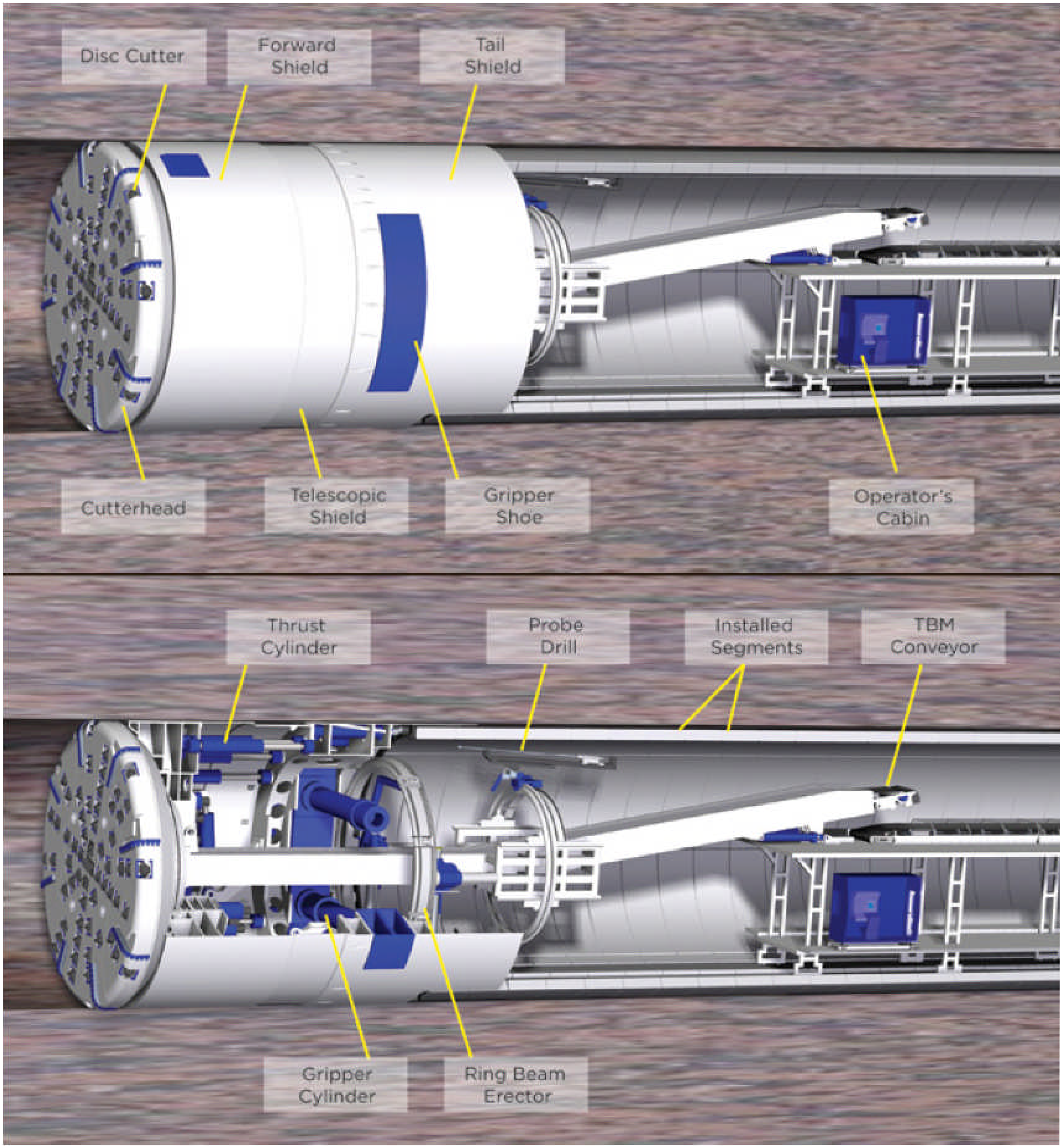
Cut and Cover Tunnel

Figure 1.4.2



Note: Tunnel Boring Machine (TBM) - Bottom Image Depits a Cut-Away View

(Courtesy The Robbins Company 2009 - Double Shield Tunnel Boring Machine Shown)

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Tunnel Boring Machine

Figure 1.4.3

Similarly, the Cut and Cover Method is eliminated from further consideration. There are significant environmental impacts that occur during the open trenching necessary for the construction of a Cut and Cover tunnel, thereby eliminating the primary advantage of the tunnel concept.

Therefore, the TBM Method is considered to be the only type of tunnel that meets the objective of avoiding or minimizing environmental impacts to the NFSLR. All subsequent discussion focuses on the TBM Method. The TBM construction method is described specifically in the Tunnel Evaluation section of this report.

2.0 Site Considerations

2.1 Horizontal Alignment and Controls

The horizontal alignment is controlled by the required flow of traffic, minimum curvature, and geometric constraints involving the area surrounding the connection points at each end. Depending upon the alternative alignments, there may be no curvature to the tunnel.

It is also important to consider environmental impacts and issues concerning right of way and connections to adjacent roadways. For example, east of the NFSLR, the tunnel length is controlled by the U.S. 1 intersection geometry. The horizontal separation of the tunnels [Section 2.3 (Tunnel Cross Sectional Requirements)] would require a transition from the wide separation of the tunnel ends to the narrower median of the roadway as the Parkway returns from depth to grade. This transition would occur over a distance of approximately 1,200 feet, before the roadway reaches the turn lanes at the U.S. 1 intersection. Because the existing intersection cannot be moved or modified without significant right of way acquisition and roadway modifications, this 1,200-foot long transition area would impact the environmentally sensitive areas east of the NFSLR.

2.2 Vertical Alignment and Controls

The vertical alignment (Figure 2.2.1) of the tunnel is controlled by the approaches and the controlling minimum depth of the tunnel underground. The graded roadway into and out of the tunnel often needs to be rather steep to minimize the tunnel length, minimize project costs, and facilitate connections to adjacent roadways and intersections.

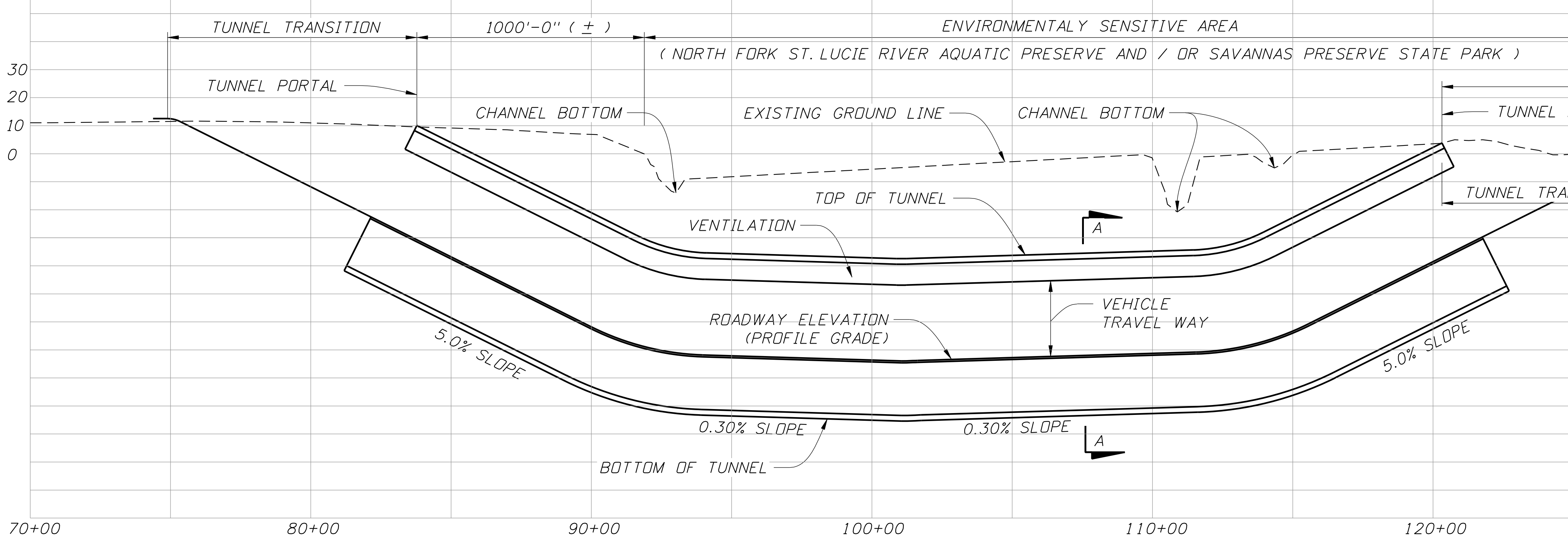
The hydrostatic pressure, which would be considered during planning and design phases of the project, is dictated by the vertical alignment of the tunnel. The existing depth of the NFLSR and tunnel cover requirement must be considered when establishing the vertical alignment of the tunnel. Critical cover locations are typically at the approach of the tunnel and at the “banks” of the waterway.

Cover is an important consideration for tunnel projects when soft ground is encountered,. Because tunnels are buoyant structures, the additional cover is necessary to keep the tunnel weighted down and secured into place. The cover requirement is dependant upon the type of tunnel chosen, the liner and ballast material, and the weight of cover material.

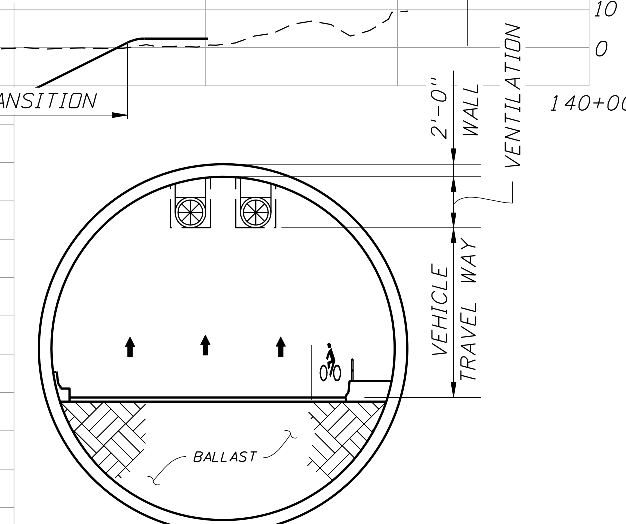
2.3 Tunnel Cross Sectional Requirements

Figures 2.3.1 and 2.3.2 graphically depict the bored tunnel cross sections for two tunnel configurations required to accommodate six travel lanes. The required clearance envelope to accommodate travel lanes, a sidewalk, superelevation, and FDOT-required vertical clearances establishes the minimum tunnel dimensions. The thickness of the tunnel walls, typically formed by precast concrete “liner” segments, is determined by the capacity of the “liners” to withstand the jacking forces necessary to advance the TBM. A clear distance equal to the

TUNNEL PLAN VIEW



TUNNEL PROFILE



SECTION A-A

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FLORIDA DEPARTMENT OF TRANSPORTATION

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FIGURE 2.2.1

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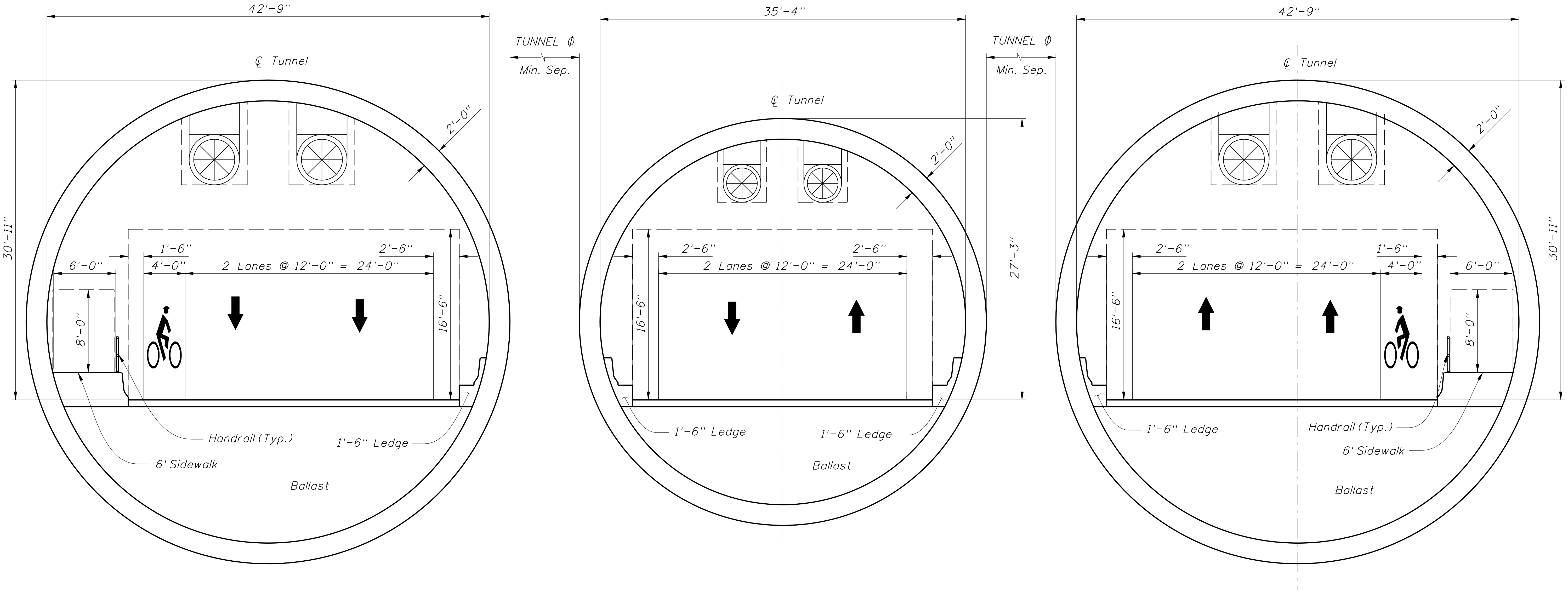

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FIGURE 2.3.1

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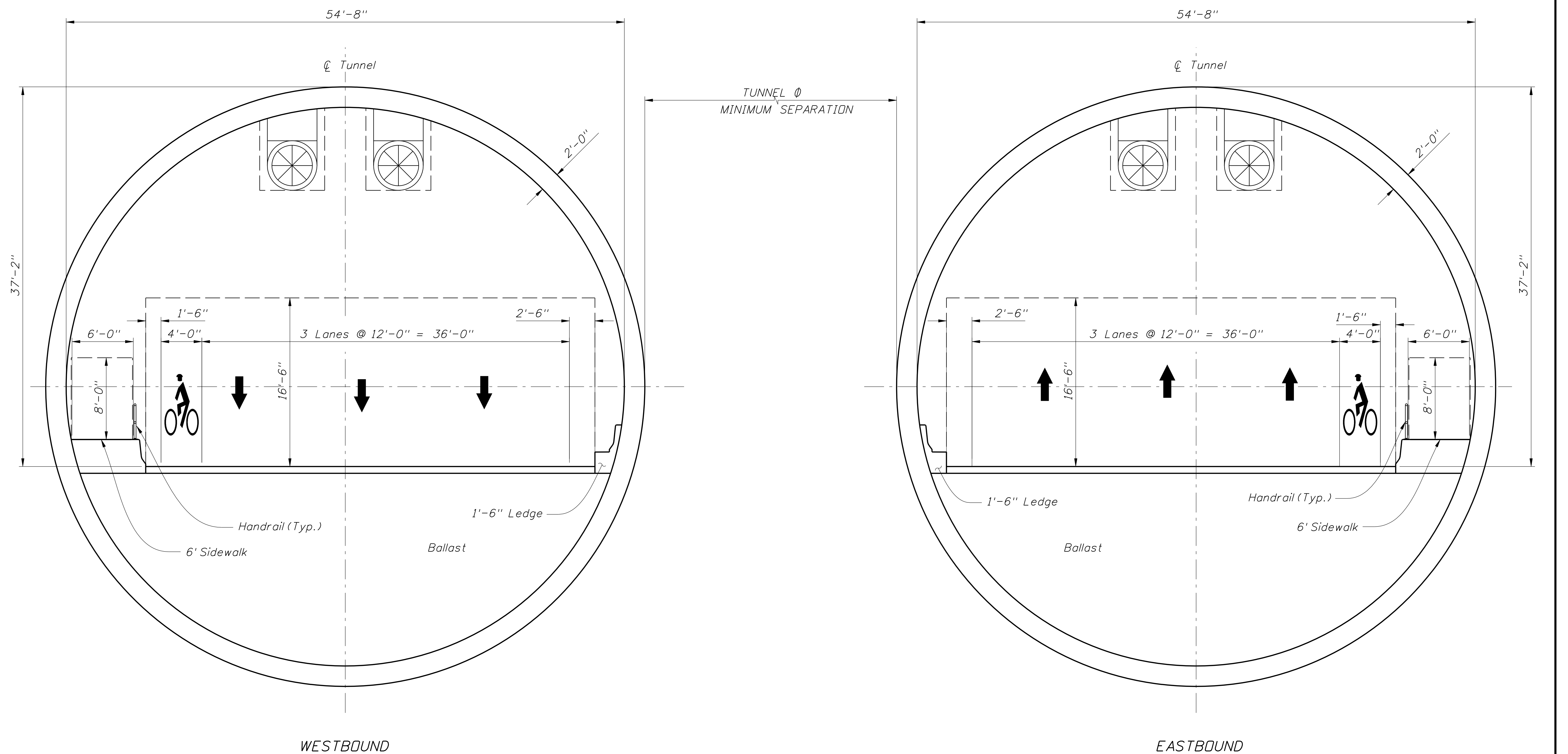

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FIGURE 2.3.2

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bforand 10/30/2009 4:46:25 PM F:\STRUCTURES\7125.II PSL Third East West Corridor EIS\cad\TunnelTypicalSections.dgn tunnel diameter is generally considered to be a reasonable clearance between adjacent bored tunnels constructed in relatively soft or porous soil conditions as found in the NFSLR.

Ventilation would also be included to carry fresh air into the tunnel and carry vehicle exhaust fumes out of the tunnel. This ventilation system may incorporate either large industrial rotor fans mounted on the ceiling of the tunnels or ducts above and below the roadway that are connected to the outside. Other considerations that would have to be incorporated into the tunnel typical section include lighting and drainage systems.

Configuration 1: 3-tunnel concept (Figure 2.3.1): Configuration 1 is based upon the maximum diameter tunnel boring machine available in the industry. As of October, 2009, the world's largest rock TBM is 47.5 feet in diameter (currently in use at the Niagara Tunnel Project in Ontario, Canada). The advantage of the 3-tunnel configuration is that TBMs of the corresponding dimensions have already been constructed. This presents the possible advantage of reusing existing TBMs either in part or in entirety, or reusing proven designs, resulting in potential reductions in initial construction costs. An alternative to the 3-tunnel concept shown in Figure 2.3.1 is to place three lanes and a narrow emergency walkway in two outside tunnels and make the center tunnel a multi-purpose pathway. This configuration would provide a different footprint, but similar complications. Disadvantages to Configuration 1 include an enlarged footprint as the underground roadway returns to grade, and geometric complications and safety issues involved with separating two 3-lane roadways into three 2-lane facilities. For these reasons, Configuration 1 is eliminated from further consideration.

Configuration 2: 2-tunnel concept (Figure 2.3.2): Configuration 2 is based upon the minimum tunnel diameter required to safely carry each 3-lane roadway underneath the NFSLR. A project-specific tunnel boring machine approximately 59 feet in diameter would need to be designed and fabricated. Based on the cost for the Tunnel Boring Machine manufactured for the Port of Miami tunnel project currently under construction, the anticipated cost of designing and fabricating a tunnel boring machine specifically for the Crosstown Parkway Extension project would be in the range of $45 million. The advantage of this configuration is that it would reduce the footprint as the underground roadway returns to grade, simplify geometry, and reduce safety issues by only requiring an increased median between the easterly and westerly roadways at the begin and end tunnel locations. It should be noted that a single-tunnel concept would require a tunnel diameter in excess of 120 feet. This is considered impractical in terms of tunnel boring. For these reasons, Configuration 2 is considered the optimal tunnel concept for the purposes of the Tunnel Concept Report. All subsequent discussion assumes this to be the case.

2.4 Cross Passages

When considering twin tunnels for traffic running in opposite directions, as has been depicted in Configuration 2, cross passages are recommended to allow vehicle occupants to safely evacuate to the opposing tunnel in the event of an emergency involving smoke and fire. For the TBM construction option, the cross passages are smaller diameter tunnels (about 16.4 feet) and are driven from one main tunnel to the other though pre-grouted and stabilized ground.

2.5 Geologic Setting

Geology is a key consideration in evaluating the constructability and cost of a tunnel. Geologic conditions such as very hard strata, very loose material, interbedded hard and soft strata, and very porous or cavernous rock can affect the location, depth, and construction methodology for the tunnel. A thorough geotechnical analysis is required in the early phases of design for any tunnel. At present, a geotechnical analysis has not been conducted for this project, but there is some limited information on the geology of the region that is pertinent for the purposes of this *Tunnel Concept Report.*

The U.S. Geological Survey has obtained hydrogeologic information from several deep wells in the County. These wells are discussed in the report "*Hydrogeology, Water Quality, and Distribution and Sources of Salinity in the Floridian Aquifer System, Martin and St. Lucie Counties, Florida*" (Ronald S. Reese, 2004, U.S. Geological Survey, Water-Resources Investigations Report 03-4242). The closest well (Well STL-334) is located approximately two miles north of the Study Area along the NFSLR. That well indicates that the Surficial Aquifer System is approximately 150 feet deep and is comprised primarily of sand with lesser amounts of sandy dolomite. The Surficial Aquifer System is comprised of the following geological formations (in order of youngest to oldest): the Holocene Pamlico Sand, the Pleistocene Anastasia Formation, the Fort Thompson Formation, and the Pliocene Tamiami Formation. These units are primarily comprised of unconsolidated and poorly lithified calcareous sands and silts interbedded with harder limestone layers.

On July 26, 1990, Keith and Schnars performed a test boring (NB-1) in the NFSLR 37 feet west of the east bank. The boring log indicates that the sediments from the river bottom (elevation -15.5 feet to elevation -67.0 feet) are medium-fine silica sands with weathered sandstone and traces of clay and shell fragments. The hardness varies considerably, with Standard Penetration Test blow counts of four blows per foot to over 50 blows per four inches.

The potential tunnel construction methods discussed herein can generally be used on the types of strata that are present in the Study Area. However, unconsolidated soft strata and potential dissolution features (cavernous rock), if present, may require drilling and injection grouting prior to excavation. Pre-tunneling solidification, if needed, would be evaluated during a geotechnical analysis. It is very important to obtain accurate geotechnical data within the area proposed for the tunnel. The cost for a geotechnical investigation for a tunnel is typically 1 to 3% of the cost of the tunnel.

To perform the geotechnical exploration, a barge must be used in the NFSLR and wetlands to drill the holes to obtain subsurface data. To accommodate the barge, two paths must be dredged over each tunnel. Also, in the upland areas, two paths must be cleared to permit access for the drilling equipment.

2.6 Ground Water Table

The ground water table is shallow throughout the region. In the project area, the ground water table elevation is anticipated to be essentially coincident with sea level (0 el.). Dewatering is a major consideration in the design and construction of tunnels. Although not generally needed for

TBM Methods, some dewatering would be required for the construction of the retaining walls at the tunnel portals (entrances).

TBM construction methods require a mechanized, full-face pressure machine to counterbalance and stabilize the soils and water pressure in the face. The tunnel would be under a head of approximately three bars pressure with a significant difference (approximately one bar) across the face of the large diameter boring machine. These pressures must be accounted for in the design of the bearings, seals, and all other machine systems, components and auxiliary equipment, as well as any pre-cast liner segments.

3.0 Bored Tunnel Construction Methods

3.1 Bored Tunnels

The current established method considered feasible for the Crosstown Parkway Extension project involves constructing the tunnel in situ using an underground excavation machine known as a Tunnel Boring Machine (TBM). The TBM has a circular cutter-head which bores through the ground. The extracted soil is then removed from the tunnel and the tunnel structure is formed using reinforced concrete panels placed along the tunnel floor, walls, and ceiling once the area has been excavated. In this way, the tunnel construction progresses in sequence, with the TBM constructing the tunnel void behind it as it moves forward. After the floor, walls, and ceiling of the tunnel are in place, the roadway and other appurtenances such as ventilation, lighting, and emergency equipment can be constructed.

The primary advantage of a bored tunnel is the minimization of environmental impacts, since this method does not require open cutting of the ground and river bed. However, there are several drawbacks and obstacles that may occur with this technique. For example, if the geotechnical investigation finds this site to be prevalently composed of porous limestone or coral bedding (common along the coast of Florida), the soil must first be pressure-grouted to create a solid mass through which to drill. Additionally, due to the size of the TBM and the extensive amount of excavated soil, substantial work areas are required at the tunnel entrances (portals) for the removal of the drill trailings by conveyor and/or other equipment. The support systems to power the TBM and remove the excavated material may extend to 350 feet in length or more.

3.2 Tunneling Cycle

Bored tunnel construction is a cyclic, repetitive process involving the advance of the tunneling shield, removal of the displaced ground, removal of the ground/mixture from the pressure chamber behind the shield using a conveyor or slurry system, and erection of the tunnel liner segments. The shield is moved forward by means of hydraulic jacks mounted to the rear of the shield reacting against the tunnel liner.

After the tunnel lining is installed, the machine moves forward, and the void between the tunnel liner and the excavated surface is filled with grout. Grouting is accomplished using grout ports that are either cast into the tunnel liner segments or within the tail of the shield. This process results in continuous contact between the tunnel liner and the ground, controlling ground movement, minimizing settlement, and reducing the potential for loss of ground flowing or reveling around the tunnel.

A redundant system of seals prevents the backflow of grout from inundating the shield. The tunnel segments are also provided with a system of compressed gaskets to provide watertight joints in the finished tunnel liner. Special concrete mixes and waterproofing coatings outside of the linings may be utilized to maximize longevity and minimize long-term maintenance.

3.3 Tunnel Ventilation

Depending on the length of the tunnel, mechanical ventilation may be necessary to control air quality in the tunnel during normal traffic flow, congested traffic conditions, and emergency situations. A critical consideration is the control of smoke during a fire. Cross passages (discussed in Section 2.4) that allow people to escape an emergency condition in one tunnel by crossing over to the parallel tunnel are also considered when evaluating ventilation and air circulation.

3.4 Pressure Face Tunneling Alternatives

The geologic and hydrologic conditions at the site suggest that the ground behavior during tunneling operations may involve running, reveling, and flowing ground. The need to control such ground losses at the tunnel face requires specialized methods for construction of the tunnel. Several alternative mechanized and pressurized face tunnel machines presently employed for the construction of tunnels in relatively soft soils and higher ground water pressures are described below.

Pressure face machines (PFM) maintain face stability and minimize ground losses by developing a positive pressure on the tunnel face within a pressurized bulkhead. The tunnel workers operate in free air (atmospheric pressure) within the PFM but behind the bulkhead. The amount of ground excavated is controlled by use of a conveyor or a displacement pump.

Within the overall class of PFMs, tunnel machines conform to two distinct soft ground excavation methods: the slurry face machine (SFM) and the earth pressure valance machine (EPB). Several notable examples of this technology have been Milan (EPB), Cairo (SFM), Madrid (EPB), Lyon (EPB), the Channel Tunnel (EPB), and undersea tunnels in Japan (EPB, SFM).

The SFM technique involves filling the excavation void with a bentonite slurry fluid to provide the necessary ground support. A return pipeline carries the mixture of excavated material and slurry to a separation plant where solids are separated from the mixture and the treated slurry product returned for reuse. Face support and ground movement around the tunnel shield are controlled by a hydraulic pressure maintained in the slurry that is at least equal to the prevailing earth (soil and water) pressure. Normal tunneling operations involve forcing the slurry into the excavated face to form a bentonite cake on the exposed ground at the front of the SFM. This creates an impermeable barrier against uncontrolled flow of water and soil. SFMs are typically considered most appropriate for use in projects involving coarse-grained soils.

In an EPB system, the cutting head functions within a void filled completely with excavated material. Face pressures are controlled by balancing the rate of advance with the rate of excavated material discharge from the conveyor. As opposed to the SFM method, the material excavated using an EPB tunneling system typically does not require treatment and emerges from the conveyor ready to be emptied into equipment for transport and disposal. However, depending on the soil conditions at the site, conditioning of the ground may be performed by the addition of bentonite, foams, polymers, and/or other additives into the face chamber, working chamber and within the conveyor. The advantage of conditioning is to modify permeability and improve workability and plasticity. The disadvantage is that conditioning may require treatment of the excavated mixture prior to disposal, similar to the SFM technique.

3.5 Tunnel Boring Machine – Compressed Air Alternative

Historically, within the large harbor cities on the east coast of the United States, tunnels excavated through soft ground involving subaqueous conditions have been built using tunneling shields under compressed air. The Holland and Lincoln Tunnels in the Port of New York, and Sumner and Callahan tunnels in Boston are examples of tunnels using this technique. Based on the depth to the tunnel invert, the maximum air pressure required for the excavation of the Crosstown Parkway tunnel will be approximately equivalent to 100 feet of water or about 3 atmospheres of pressure. Compressed air tunneling does not appear to be an appropriate means for this project due to the availability of new technology and the excessive decompression time which would be required for compressed air workers.

4.0 Environmental Impacts

This section briefly describes some of the socio-cultural and environmental impacts of tunnels as compared to bridge alternatives. It is intended to be general in nature, since a thorough investigation was not conducted as part of this *Tunnel Concept Report.*

4.1 Social Impacts

4.1.1 Land Use Changes

The total economic impact on the community for a tunnel is likely to be higher than the impact of a bridge alternative. Additional roadway right of way would be required due to the tunnel separation, requiring an enlarged median area at the tunnel portals. The roadway would dive down into the tunnel, with the approaches forming a physical barrier east and west of the NFSLR approximately 1,200-foot long.

The economic impacts in terms of residential and business relocations, financial impacts, and impacts on property taxes could be slightly higher than a bridge alternative due to the additional right of way required.

The tunnel alternative may have more direct impacts on utilities than the bridge alternative. Since the roadway drops into the tunnel, any utilities in conflict would require relocation.

4.1.2 Community Cohesion

The development of a 6-lane divided roadway as it approaches a tunnel would substantially change the visual context of the community and would create a physical barrier that would divide the neighborhood into segments. However, this is also true for the bridge approaches required for a bridge alternative.

4.1.3 Additional Analysis – Social Impacts

During the review of the Draft Environmental Impact Statement, the U.S. Army Corps of Engineers suggested the tunnel alternative be further evaluated with an alignment along Alternative 1F or 6B because the eastern terminus could come to grade within upland habitat (thus avoiding wetland impacts). Alternatives 1F and 6B would have the same alignment on the eastern side of the NFSLR, but Alternative 1F was chosen for this analysis because it would have fewer social impacts on the west side of the NFSLR.

From the traffic analysis conducted for this study (detailed in the technical support document titled *Design Traffic Technical Memorandum*), the eastbound traffic queues for the Crosstown Parkway Extension along Alternative 1F would be 700 feet. The transition from the tunnel cross section width to the urban typical section width would occur over a distance of approximately 1,200 feet. As a result, the tunnel would begin approximately 1,900 feet west of the U.S. 1 intersection along the Alternative 1F alignment. This would intrude into the wetlands along the south side of the Alternative 1F alignment behind the Liberty Medical site, resulting in approximately three acres of wetland impacts. To avoid the wetlands, the alignment would need to be shifted to the north. A bridge along this alignment would require 21 residences be relocated from La Buona Vita which is a cooperative community. Shifting the tunnel northward to avoid wetland impacts would require the need to purchase and relocate an additional 17 or 18 residences within La Buona Vita (for a total of 38 or 39) within this community.

4.2 Cultural Impacts

4.2.1 Historical and Archaeological Sites

No substantial historical or archaeological sites are known to exist in the project area. Based on the results of the technical report titled *Cultural Resource Assessment Survey* conducted for the project, the overall potential for historical or archaeological sites is considered low in the area, and any potential impacts would be comparable to a bridge alternative.

4.3 Natural Environment

4.3.1 Wetlands

The primary advantage of the TBM method is that impacts to wetlands can be minimized. The machine travels below the ground and the river bottom, thereby leaving the existing ground and surface waters undisturbed.

Although the tunnel can extend as far as necessary on the west side of the NFSLR to avoid impacts to environmentally sensitive areas, geometric constraints to connect to the roadways on the east side of the River would result in impacts to environmentally-sensitive areas. Therefore, a tunnel could avoid most, but not all, wetland impacts.

Based on geology of the area discussed in Section 2.5 (Geologic Setting), the soil is likely unsuitable (too soft) for effective use of the TBM. Therefore, soil stabilization (the injection of dry cement like material into the soil) would likely be required to create a suitable material for the TBM. This would be accomplished through pressure grouting which would cause environmental impacts due to equipment placement and construction methods. Clearing would be necessary in uplands, and dredging would be required in the Aquatic Preserve above the proposed tunnel locations to accomplish this. Additionally, as with any tunnel project, there is the potential for heave, settlement, influence on ground water, chemical grouting, construction by-products, leakage of underground oxygen-deficient air/hazardous gases, and pushing organic material or iron-content soil into nearby wells if present.

4.3.2 Wildlife and Habitat

The primary advantage of the TBM method is that impacts to wildlife can be minimized. The machine travels below the ground and the river bottom, thereby leaving the existing ground and surface waters, fish life, migratory routes, etc. undisturbed. By boring under wildlife habitat, TBM impacts would be limited to those temporary in nature such as ground vibration during boring operations, and the construction impacts associated with pressure grouting discussed above.

4.3.3 Additional Analysis – Natural Environment

As noted in Section 4.1.3 (Additional Analysis – Social Impacts) a tunnel along the Alternative 1F alignment would intrude into the wetlands along the south side of the alignment behind the Liberty Medical site, resulting in approximately three acres of wetland impacts. To avoid the wetlands, the alignment would need to be shifted to the north, requiring the need to purchase and relocate an additional 17 or 18 residences within La Buona Vita. Further, a tunnel along the alignment of Alternative 1F would have similar issues associated with potential construction impacts within the natural environment as discussed above.

4.4 Physical Impacts

4.4.1 Noise

The residential land uses in this area are sensitive to increases in noise. The tunnel alternatives, however, would reduce the noise level as compared to a bridge alternative within certain defined areas. As traffic descends into a tunnel, most of the traffic noise would be confined within the walls of the approaches and within the tunnel itself. However, while a tunnel may improve overall noise levels compared to those of a bridge alternative, there would be a concentrated increase in noise level at the tunnel entrances due to the location of the tunnel ventilation system fans and any tunnel-associated powering equipment.

4.4.2 Air Quality

The traffic levels and flow characteristics for the tunnel alternatives would be similar to a bridge alternative. As such, the total air emissions may be comparable. Further air quality analysis would be required to determine point source emissions and receptor locations. For a tunnel alternative, carbon monoxide gas would be vented to the ends of the tunnel as opposed to distribution across the entire length of a bridge. A ventilation system would be required that maintains the quality of the air within the tunnel, as well as the air released, within acceptable levels as required by the U.S. Environmental Protection Agency (USEPA). Local and regional air quality would not be improved by the construction of a tunnel as a result of the vehicle exhaust expelled from ventilation structures at the tunnel portals as a concentrated point source.

4.4.3 Visual Impacts

On either side of the NFSLR, the visual impacts associated with a tunnel are similar to a bridge alternative. The ventilation and power equipment at the tunnel portals, and the tunnel portals themselves, can be concealed by visual barriers such as landscaping and vegetation or berms. Additionally, during construction, should work occur at night, lighting would be limited to the tunnel entrance areas reducing any temporary visual impacts. For recreational boaters on the River, a bridge would have a negative visual impact on the scenic NFSLR, whereas a tunnel would not be evident from the NFSLR.

4.4.4 Contamination

No contaminated sites are known to exist within the potential right of way of the build alternatives. If contamination is found, it would need to be managed the same regardless of whether the project includes a bridge or tunnel.

5.0 Costs

A review of similar tunnel projects constructed since 1990 was conducted to determine anticipated cost ranges for the Crosstown Parkway Extension tunnel. One similar project that is under construction is the Port of Miami Tunnel Project, which will provide direct access between the Seaport, I-395, and I-95. Based on the bid submitted by the Miami Access Tunnel Team, the cost of construction for the Miami Tunnel Project (using the TBM method) is approximately $610 million for the 3,900-foot long tunnel portion of the project, resulting in a cost of $155,000 per foot of tunnel.

The crossing of the NFSLR would be between 2,200 to 4,500 feet long depending on the selected alignment of the roadway. Additionally, the Crosstown Parkway Extension tunnel utilizes a larger diameter tunnel than that of the Miami Tunnel Project, and would require the design and manufacture of a project-specific TBM, using what would be the largest TBM in the world to bore the first three lanes in one direction and then bore the second tube. For the purposes of this *Tunnel Concept Report*, using the Miami Tunnel figure of $155,000 per foot, the tunnel would cost $341 to $698 million depending upon the selected alignment and length.

The cost for designing and manufacturing the TBM for the Miami Tunnel Project was $45 million according to the Frequently Asked Questions section of the Miami Tunnel Project web site (www.portofmiamitunnel.com/faqs/tunnel-boring-machine/). A similar cost would be anticipated for this project.

Estimates for construction of a bridge alternative (excluding roadway portions) range from $52 million to $89.3 million based on the alternatives studied for the Crosstown Parkway Extension EIS.

6.0 Conclusions and Recommendations

6.1 Comparative Analysis

Following is a summary of the primary advantages and disadvantages of using TBM construction compared to the use of a low-level fixed bridge.

<u>Tunnel Advantages</u>

Environmental Impacts

Tunnel construction would result in less wetland and wildlife impact to the NFSLR by crossing beneath the river and floodplain.

Aesthetics

From the River, since the only visible structure above ground would be the tunnel portals, the tunneling alternative would be more visually pleasing than a bridge which cuts across the view of the river.

Waterborne Traffic

No impact would be made to the waterborne traffic on the NFSLR since the tunnel's structure would be located underground. This advantage is minimal because the bridge would be designed to meet U.S Coast Guard navigational requirements.

<u>Tunnel Disadvantages</u>

Environmental Impacts

The tunnel will require a channel dredged above the proposed tunnel for equipment to drill holes and for pressure grouting the soil above all the tunnels to be drilled. A tunnel will also have some impact to wetlands due to the width of the cross section, and the transitional length necessary at the tunnel portals (see also geometric constraints below).

Pedestrian Concerns

Depending upon the selected alignment, a tunnel would enclose pedestrians for a distance of approximately three quarters of a mile. This may be considered a security and liability problem, and in some ways may be considered detrimental to the pedestrian-friendly environment prevalent along the existing Crosstown Parkway. Construction of a pedestrian bridge to counter enclosure-related issues would add more cost to the project and inherently involve additional environmental impacts as well.

Safety

As a hurricane evacuation route, the corridor would be susceptible to catastrophic accidents and have limited emergency access and escape routes. Raising the tunnel opening above the 100 year floodplain elevation or the storm surge level for a Category 5 hurricane would increase the overall tunnel length and add cost to the project. Emergency flood gates or doors could be used at additional cost, but would prevent the tunnel from acting as a possible hurricane evacuation route.

Geometric Constraints

At the east end of the crossing, geometric constraints will inhibit tunnel construction since there is not adequate distance for the depressed roadway section to return to existing grade and tie-in to existing roadways and intersections without impacting a portion of the River's resources, and thus reducing the tunnel's primary benefit of avoiding impact to the existing environment.

Security

Given the enclosed nature of the tunnel and the required ventilation and electrical systems, it would be more susceptible to an incident of attack than a bridge alternative.

Property Impacts

The tunnel would have greater effects to nearby properties than a bridge alternative, because property acquisition would be required to descend at each entrance to the necessary boring depth. Additionally, a tunnel would be wider than a comparable bridge to accommodate the required tunnel separation and multiple support systems. Further, due to the extensive amount of excavated soil, substantial work areas would be needed at the tunnel entrances (portals) for the removal of drill tailings.

Air Quality and Noise Level

Although overall emissions would be similar, the vehicle exhaust expelled from ventilation structures at the tunnel portals would be a concentrated point source. Regarding noise, while a tunnel may improve overall noise levels, there would be a concentrated increase in noise level at the tunnel entrances.

Cost

Substantially higher construction costs are associated with the underground excavation methods, including the cost of the specialized Tunnel Boring Machine and its supporting equipment. A tunnel would also involve higher operation and maintenance costs than a bridge alternative for wall washing, security, and the energy costs of the lighting, ventilation, and drainage systems.

6.2 Recommendations

Based upon preliminary review, a tunnel appears to be a technically-feasible solution for crossing the NFSLR. Also from an environmental standpoint, the TBM tunneling method would involve less environmental impact to wetlands and wildlife when compared to a bridge alternative.

However, the tunnel would not avoid impacts to the environment without considerable additional impacts to nearby residences and businesses. In comparison to the bridge alternatives, the construction of a tunnel creates several geometric and safety issues; has greater property impacts; involves substantially higher construction, operational, and maintenance costs; and presents a higher safety and security risk.

6.2.1. Additional Analysis Along Alternative 1F Alignment

Based on this assessment, it was concluded that construction of a tunnel along the Alternative 1F alignment would be feasible. However, this alternative is not practicable because:

- It would have greater social impacts than a bridge alternative by encroaching into the neighborhoods at the western and eastern termini. The tunnel would have a wider right of way width than a bridge (177 feet for the tunnel versus 155 feet for the bridge);
- Although it could be constructed to avoid the use of the Savannas Preserve State Park and associated wetlands, by shifting its alignment north of the bridge alignment, the tunnel alignment would require the relocation of 17 to 18 additional residential relocations in La Buona Vita community compared to a bridge along the same alignment (21 relocations within La Buona Vita are required for a bridge along Alternative 1F, and 38-39 relocations are required for a tunnel option along the alignment of Alternative 1F); and
- It would have the same increased right of way requirements, need for soil stabilization, potential construction impacts, reduced flexibility during emergency evacuation events, limited pedestrian and bicycle usage, and increased costs as described for the tunnel alternative along Alternative 1C.

6.2.2. Conclusion

Based on this evaluation, while it is feasible to construct a tunnel to completely avoid the wetlands associated with the Savannas Preserve State Park and the Aquatic Preserve, to do so would have substantial social impacts and considerable costs as compared to a bridge alternative. Because of these implications, the tunnel alternatives have been determined to be not practicable. Therefore, it is recommended that the tunnel concept be eliminated from further consideration.